SURFACE COATING, CEMENT MORTAR:
ANTI-CARBONATION EFFECT

Key words: Test method, surface coating, carbonation

1 SCOPE
This Nordtest Method specifies a procedure for the determination of the anti-carbonation effect of a surface coating system on concrete (cement mortar).

The anti-carbonation effect is determined by accelerated comparative testing of coated and uncoated specimens.

2 FIELD OF APPLICATION
The method is suitable for comparing the performance levels of surface coating systems on concrete (cement mortar). Coating systems may include complete surface coating systems or parts of coating systems including brittle materials and non-film forming materials. The uncoated reference is usually untreated concrete (cement mortar); if relevant another reference, e.g. smoothed/levelled concrete (cement mortar), can be included.

3 REFERENCES

See Annex concerning background information.

4 DEFINITIONS
Carbonation: Carbonation occurs when concrete is in contact with carbon dioxide, e.g. CO\textsubscript{2} in atmospheric air. CO\textsubscript{2} reacts with the liquid in the concrete pores according to the (main) reaction:
\[
\text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}
\]
Carbonation neutralises the strongly alkaline environment of the concrete.
Carbonation front: The boundary layer in which the phenolphthalein colour change takes place.
Depth of carbonation: The distance from the surface to the carbonation front measured in millimetres (uncoloured area indicates carbonated concrete).

5 SAMPLING
For tests on one surface coating system, three specimens coated with the system to be tested and three uncoated specimens are needed for each substrate. If an extra set of
reference specimens, e.g. smoothed concrete (cement mortar), is included, three more specimens are needed for each substrate.

The specimens to be coated and the extra reference specimens (optional) are to be treated on two opposite sides. Only sides vertically placed during casting should be used as the two opposite sides to be tested. The other sides are to be made carbon dioxide tight. Untreated specimens must be sealed similarly on all except two opposite sides.

Recommended minimum size of cement mortar specimens: 40 x 40 x 160 mm, resulting in a dimension of opposite test sides: 40 x 160 mm.

All concrete (cement mortar) specimens used in a determination must come from the same batch and must be cured and stored identically. If nothing else is specified the substrates must be conditioned for a minimum of 4 weeks in a standard conditioning atmosphere of 23 ± 2 °C and 50 ± 5 % relative humidity before the coating is applied.

The two opposite test sides are usually sand wheel blasted and possibly smoothed before applying the coating system in order to obtain well defined smooth surfaces free of particles, chalking and pores.

The application of the coating is carried out according to the specifications given by the suppliers and the following parameters are recorded for each application:

- application method
- thinning
- consumption per m²
- time interval between coatings
- temperature and relative humidity during application and curing.

6 METHOD OF TEST

Determination of the anti-carbonation effect is carried out according to the method described below.

Determination of dry film thickness (optional) is carried out according to ISO 2808-1974 method No. 4A: Microscopy of a cross-section.

6.1 Principle

Coated and uncoated specimens are placed in a chamber and exposed to a flow of humid air containing carbon dioxide.

The carbon dioxide that is able to diffuse through the surface coating system reacts with the concrete (cement mortar) causing carbonation.

The rate of carbonation is determined by cutting slices of the specimens at predetermined equal time intervals. Application of a phenolphthaleine indicator solution colours the uncarbonated concrete purple and leaves the carbonated concrete uncoloured. The depth of carbonation can then be measured and the rate of carbonation calculated.

6.2 Apparatus

- Sealant (carbon dioxide tight, e.g. waterborne epoxy-paint).
- Exposure chamber with gas inlet and outlet (a convenient size is 700 x 500 x 700 mm).
- Equipment able to supply the test gas (20 ± 3 vol% carbon dioxide in atmospheric air, 65 ± 10 % relative humidity).
- Gas flow control; e.g. flowmeter and valve(s).
- Fan (to give uniform conditions inside the chamber).
- Humidity control, e.g. a dew point meter with RH reading.
- Cutting device to cut off concrete slices, e.g. a diamond cutter.
- Wax.
- Phenolphthaleine solution (10 g/litre in solution of 70 % ethanol and 30 % demineralized water, parts by volume).
- Ruler, millimetre scale.
- Microscope, e.g. Vertical Auflichtmikroskop, Carl Zeiss Jena (optional).

6.3 Preparation of test samples

All sides of the specimens except the two opposite test sides are made carbon dioxide tight by application of a sealant.

Unless otherwise specified the specimens are kept for a minimum of 4 weeks in a standard atmosphere of 23 ± 2 °C and 50 ± 5 % relative humidity before testing.

6.4 Procedure

Unless other test conditions are specified the following conditions are suggested.

- CO₂ concentration: 20 ± 3 % by volume
- Relative humidity: 65 ± 10 %
- Temperature: 23 ± 3 °C
- Gas exchange: approx. 10 % per hour
- Uniform conditions at all test locations.

The conditions should be considered carefully with regard to the rate of carbonation and should be specified.

Before exposure a slice (40 x 40 x approx. 10 mm) is cut off the specimens in order to determine the carbonation level of unexposed specimens. The cut surface of the concrete slice is wetted with phenolphthaleine solution immediately after cutting.
The depth of the carbon dioxide penetration is measured directly in millimeters with a ruler. For specimens with an irregular carbonation front the depth of carbonation is recorded as an interval. If pores in the coating give an irregular carbonation front, the recorded interval should be accompanied by a remark about pore(s). The cut surface of the remaining specimen is waxed carbon dioxide tight within two hours after cutting, and the specimen is ready for exposure.

The specimens prepared for test are placed in the exposure chamber with the two opposite test sides vertical, with a minimum distance of 10 mm between the specimens. The specimens are exposed to the testing atmosphere for a total of 8 days (4 times 48 ± 1/4 hours) if nothing else is agreed upon. An extension of exposure time can e.g. consist of 8 additional days (in total: 4 times 48 ± 1/4 hours followed by one period of 192 ± 1/4 hours).

A slice is cut off the specimens at the end of each 48 hour period. The cut is made within the day on which the specimens are removed from exposure. The cut surfaces are wetted by phenolphthaleine solution (slice) or waxed (remaining specimen) as described above. Between the exposure periods the specimens are placed in a laboratory atmosphere of 18 - 25 °C and a relative humidity ≤ 50 %.

The test for anti-carbonation effect is carried out as a triple determination.

Determination of dry film thickness according to ISO 2808-1974 method No 4A can be carried out as a supplement to the applied amount of coating recorded during application.

6.5 Expression of results

The selected parameters may be expressed as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Dimension/definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity, relative</td>
<td>RH</td>
<td>%</td>
</tr>
<tr>
<td>Temperature</td>
<td>t</td>
<td>°C</td>
</tr>
<tr>
<td>Time</td>
<td>d</td>
<td>24 hours = 1 day (= 1 d)</td>
</tr>
<tr>
<td>Depth of carbonation</td>
<td>cd</td>
<td>mm</td>
</tr>
<tr>
<td>Rate of carbonation</td>
<td>cv</td>
<td>mm/day</td>
</tr>
</tbody>
</table>

The results are given as relative values i.e. carbonation of coated specimens compared with uncoated (reference) specimens made from the same batch.

Depth of carbonation, cd, can be plotted as a function of exposure time, as shown in Appendix 2.

The rate of carbonation, cv, is given as an average of 8 days of exposure. If the exposure is extended the rate of carbonation is given as an average of 8 days as well as an average of the total exposure time.

6.6 Accuracy

The registration limit of the method is a depth of carbonation of approx. 0.5 mm, equivalent to < 0.1 mm/day expressed as rate of carbonation after 8 days of exposure.

6.7 Test report

The test report shall include the following information, if relevant:

a) Name and address of the testing laboratory.

b) Identification number of the test report.

c) Name and address of the organization or the person who ordered the test.

d) Purpose of test.

e) Method of sampling and other circumstances (date and person responsible for sampling).

f) Name and address of manufacturer or supplier of the tested object.

g) Name or other identification marks of the tested object.

h) Description of the tested object.

i) Date of supply of the tested object.

j) Date of test.

k) Test method.

l) Conditioning of the test specimens, environmental data during the test (temperature, pressure, RH, etc.).

m) Identification of the test equipment and instruments used.

n) Any deviations from the test method.

o) Test results (use SI units).

p) Inaccuracy or uncertainty of the test result.

q) Date and signature.

7 ANNEX

Background information:

R 44-88/TI-0 “Karbonatiseringsbremsende overfladebe-skyltelse, laboratorieundersøgelse og metodeudvikling. (Surface protection to prevent carbonation, laboratory investigation and method development).


Enclosure

Appendix 1: Test report forms

Appendix 2: Diagram
**TEST REPORT FORMS**

Name and address of the testing laboratory

Surface coating on concrete (cement mortar). Determination of anti-carbonation effect

Client:

Coating system for testing:

<table>
<thead>
<tr>
<th>Trade name</th>
<th>Producer</th>
<th>Type: MBK (Catalogued professional treatments)</th>
<th>Coat No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
</tbody>
</table>

Data of coated test specimens:

<table>
<thead>
<tr>
<th>Concrete substrate</th>
<th>Cement mortar 0.6</th>
<th>Cement mortar 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>water-cement ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of test specimens</td>
<td>3( )</td>
<td>3( )</td>
</tr>
<tr>
<td>Number of test specimens (coding)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method and date of application</td>
<td>Coat No. 1</td>
<td>Coat No. 2</td>
</tr>
<tr>
<td>Consumption per m²</td>
<td>Coat No. 3</td>
<td>Coat No. 4</td>
</tr>
<tr>
<td>Coating interval</td>
<td>Coat No. 1 - 2</td>
<td>Coat No. 2 - 3</td>
</tr>
<tr>
<td></td>
<td>Coat No. 3 - 4</td>
<td></td>
</tr>
<tr>
<td>Dry film thickness</td>
<td>ISO 2808-74,4A - optional</td>
<td></td>
</tr>
<tr>
<td>Treatment of sides not to be tested.</td>
<td>Date and sealant type</td>
<td></td>
</tr>
<tr>
<td>Special notes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Data of uncoated test specimen:

<table>
<thead>
<tr>
<th>Concrete substrate</th>
<th>Cement mortar 0.6</th>
<th>Cement mortar 1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of test specimens</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of test specimens (coding)</td>
<td>3( )</td>
<td>3( )</td>
</tr>
<tr>
<td>Number of smoothed test specimens (coding)- optional</td>
<td>( )</td>
<td>( )</td>
</tr>
<tr>
<td>Smoothing material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method and date of smoothing. Consumption per m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry film thickness ISO 2808-74,4A - optional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment of sides not to be tested. Date and sealant type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Special notes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Exposure**

Date:

Exposure periods:

CO₂-concentration:

Relative humidity:

Temperature:

**Result form:**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Object</th>
<th>Carbonation Depth** in (mm) after exposure for</th>
<th>Rate * (\text{mm/day})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0 days</td>
<td>2 days</td>
</tr>
<tr>
<td><strong>Coating</strong></td>
<td><strong>Substrate</strong></td>
<td><strong>No.</strong></td>
<td></td>
</tr>
<tr>
<td>Uncoated</td>
<td>Cement mortar 0.6</td>
<td>U-0.6</td>
<td>1</td>
</tr>
<tr>
<td>Unsmoothed</td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Cement mortar 1.0</td>
<td>U-1.0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncoted smoothed</td>
<td>Cement mortar 0.6</td>
<td>X-0.8</td>
<td>1</td>
</tr>
<tr>
<td>(optional)</td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Cement mortar 1.0</td>
<td>X-1.0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coated</td>
<td>Cement mortar 0.6</td>
<td>A-0.6</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Cement mortar 1.0</td>
<td>A-1.0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**For specimens with irregular carbonation an interval is given (e.g. 6-11). If the two sides of a specimen show a different front both intervals are given (e.g. 0-1 / 2-6).**

**Rate of carbonation is given as an average of 8 days of exposure.**

**Comments:**

Relative depth of carbonation

Relative rate of carbonation

**Signature**

The result of this test is only to be stated in full; in extract only by written permission from the testing laboratory.

**Enclosed**

**Diagram**